United States Department of the Interior
Fish and Wildlife Service

Fishery Leaflet 155

Chicago 54, Ill. December 1945

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PACIFIC OCEANIC FISHERY
INVESTIGATIONS

DRY ICE REFRIGERATION OF FRESH FISH FILLETS 1/

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During the past several years, various attempts have been made to use solid carbon dioxide (dry ice) as a refrigerant in packing fresh fish for shipment. Owing to the difficulty of controlling the temperature and preventing freezing, the method has not been generally used for unfrozen fish. However, recent restrictions placed on the use of tinplate in the manufacture of fillet boxes for shipping fish fillets packed in ice has created a need for further study of this method of refrigeration.

In the course of investigations by the Fish and Wildlife Service on non-metallic containers for packaging fish, experiments were conducted to test fibre fillet boxes refrigerated with dry ice. The fillet boxes were packed in corrugated fibre containers and were insulated from the dry ice by recently invented pads designed for this purpose. The studies were made at the Service's Technological Laboratory, College Park, Maryland, in cooperation with the Merkle Corporation and the Container Corporation of America, both of Philadelphia, Pennsylvania. The first mentioned firm furnished the Merkle insulating pads and the second furnished the fibre fillet and corrugated boxes.

Description of Package--A shipping unit holding two 20-pound packages of fillets was chosen as being the most satisfactory from the standpoint of trade practice and ease in handling. Initial experiments were made to determine the proper sizes of the shipping container and the fillet boxes, the most effective distribution of the dry ice, and the proper amount of insulation to prevent the fillets from freezing.

The fillet boxes were of the telescopic type, and constructed of lightly-waxed fibreboard 1/16 inch in thickness. The inside dimensions of these boxes were $21\frac{1}{4}$ by $10\frac{1}{4}$ by $2\frac{3}{4}$ inches. A typical 20-pound tin fillet box measures approximately 15 by $10\frac{1}{2}$ by 4 inches. The longer and more shallow fibre fillet box was selected in order to obtain more rapid cooling of the fillets and more uniform temperatures. The size was such that 20 pounds of fresh haddock or cod fillets completely filled the box.

A corrugated container or "ice box" was used for each shipping unit to hold the dry ice and to prevent the movement of the contents within the shipping container. The inside measurements of the "ice box" were 21-9/16 by 10-5/8 by 4 inches, and the board was 3/16 inch thick. The "ice box" was prepared in advance, so that it could be placed as a unit between the two fillet boxes in the shipping container. Two slabs of dry ice, wrapped in ordinary single thickness wrapping paper, or in a few thicknesses of newspaper, were placed inside the "ice box" horizontally sandwiched between two Merkle insulating pads. By placing the dry ice between the packages of fish fillets a more symmetrical arrangement was possible. Satisfactory refrigeration would then be maintained if the packages were accidentally inverted.

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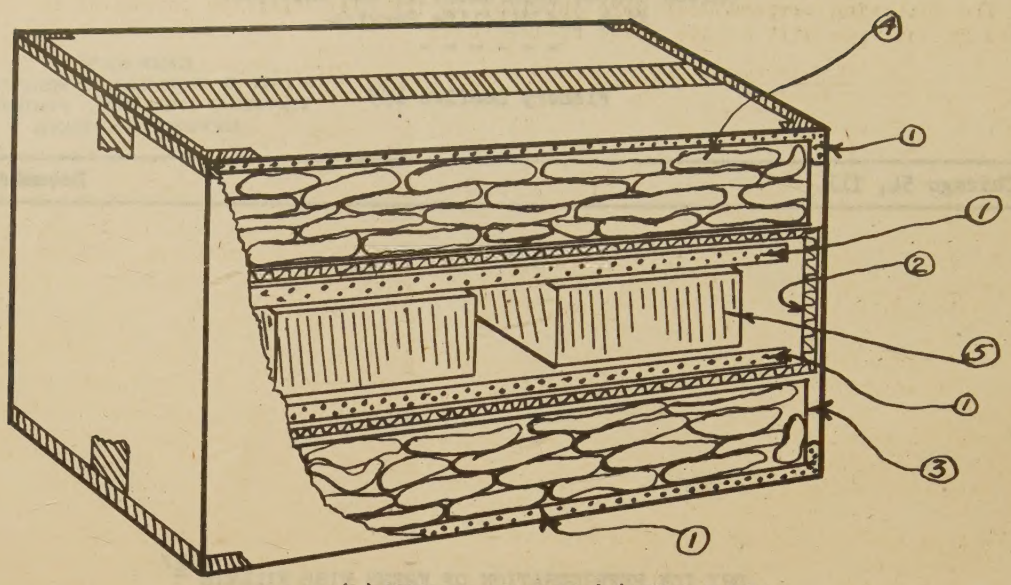
1/ This leaflet supersedes Sep. 32, a reprint from Fishery Market News, August 1943, pages 7-10.



(1) MERKLE PAD (3) FILLET BOX

(2) "ICE BOX" (4) HADDOCK FILLETS

(5) DRY ICE

In the early tests, a flexible 14-ply Merkle insulation pad was used below the dry ice, and a 6-ply flexible pad over it when the "ice box" was prepared. Reasonably good control of the refrigerating action of the dry ice was secured. In later experiments, the insulation under the dry ice was changed to a rigid 6-ply Merkle pad, 1¼ inches thick, and that over the dry ice to a flexible 2-ply Merkle pad. This insulation combination was used in the "ice box" for all subsequent tests.

The recommended shipping container was constructed of A and B fluted, corrugated paperboard, 5/16 inch in thickness. The inside dimensions, 22-3/8 by 11½ by 12 inches, were such that there was a small space between the walls and the fillet boxes, which was filled by carbon dioxide gas from the dry ice, which in turn acted as insulation. The container was so cut that the top and bottom side flaps fitted snugly end to end, giving the maximum structural strength and best conditions for thorough sealing.

Method of Packing--In packing the shipping container, a 4-ply Merkle pad, 25-3/8 by 11-3/8 inches, was placed in the bottom. The length of the pad was sufficient to give a 1½ inch overlap turned up at each end, making it possible to reduce thermal leakage by covering the seams and cracks in the bottom of the shipping container with an insulating material.

A fillet box holding 20 pounds of fresh fish fillets, precooled to 38° to 40° F. for moderate outside temperatures or lower for very warm outside temperatures, was set on the insulating pad which overlapped each end of the box. The "ice box", which was previously assembled with a suitable amount of dry ice, was placed above the fillet box, followed by the second fillet box. A 4-ply pad similar to that used for the bottom of the container was placed over the top fillet box, and the overlapping ends were bent down around the ends of the box. The shipping container was then thoroughly sealed with heavy three-inch gummed tape.

Experimental Results--A package containing 40 pounds of fresh cod fillets was held in a room in which the temperature was maintained at approximately 70° F. continuously during the test. The temperature was obtained on a recording resistance thermometer by means of thermocouples placed in various parts of the package. The package was not disturbed at any time during the test.

The following temperatures were obtained in the fish when 23½ pounds of dry ice were placed in the "ice box" at the start of the test:

Time in Hours	Degrees Fahrenheit
At start	37 to 41
24	30 to 38
48	29 to 36½
67	30 to 37½

Four pounds of dry ice remained at the end of the test. One fish fillet had a slight surface freeze or "nip" on the side closest to the dry ice. A slight surface freezing or "nipping" on the layer of fillets closest to the dry ice was considered desirable, since it was indicative of near freezing temperatures. The appearance and odor of the fillets were unchanged.

In general, it was found that when packages containing small amounts of the dry ice were resealed and held overnight in a refrigerated cold room at 40° to 45° F. without additional dry ice, the temperature of the fish rapidly dropped to 30° to 32° F. These cold temperatures were maintained as long as the dry ice remained. These findings suggest that packages containing small amounts of dry ice may be stored in cold rooms on receipt of shipment without additional icing.

Packaging Periods--Experiments were performed to determine the amount of dry ice that was necessary for different periods of refrigeration at outside temperatures of approximately 70° F. The amounts of dry ice in the "ice box" were varied, and the temperature of the fillets recorded. Each test was continued until the temperature in the fillets began to rise rapidly.

The data on quantity of dry ice used for different periods of satisfactory refrigeration are presented in Table 1.

Table I - Pounds of Dry Ice Used in a Shipping Package Containing Two 20-pound Fibreboard Boxes of High Quality Unfrozen Cod or Haddock Fillets for Varying Periods and Outside Temperatures

Period of Packing	Outside Temperature Range, Degrees Fahrenheit		
	35-55	55-75	75-90
Hours	Pounds	Pounds	Pounds
24	7-9	12-13	16-22
36	11-14	17-18	24-30
48	15-17	20-21	28-34
60	18-19	22-23	*
72	19-22	25-26	*
96	23-27	30-31	*

*Tests under these conditions were unsatisfactory.

Experiments were also performed to determine the effect of outside temperature on the length of satisfactory refrigeration. It was found that when a shipping package contained 22 to 24 pounds of dry ice for each 40 pounds of fillets, satisfactory refrigeration was obtained for 36, 60, and 96 hours, respectively, for hot, moderate, and cold outside temperatures.

High temperatures outside the package had a considerable effect on those within the container. When the temperature was as high as that commonly encountered during hot weather, the temperature of some of the fish farthest from the dry ice rose beyond desirable limits, although a large excess of dry ice was used. In a typical 48-hour experiment, during which the outside temperature varied from 75° to 90° F. the following temperatures were recorded in the fish fillets:

Time in Hours	Degrees Fahrenheit
At start	44½ to 48
24	35 to 42
48	33 to 52½

After 48 hours the temperature rose rapidly. The same effects were obtained in all the experiments at high outside temperatures. It is to be noted that the higher temperature was found in fillets in the ends of the boxes which are farthest from the dry ice; whereas, the colder temperature was found in the greater proportion of the fish.

Discussion--When the shipping package containing 40 pounds of fillets was kept continuously at outside temperatures of 75° to 90° F. for more than 48 hours, unsatisfactory temperatures, above 50° F., were obtained in parts of the containers farthest away from the dry ice. Therefore, at high outside temperatures, packaging is limited to periods of 48 hours or less. If the package is placed in a cooled atmosphere, as in a refrigerated car or truck, the period can be extended considerably beyond the 48-hour period. Successful packaging tests for periods up to 90 hours duration have been made when the outside temperature varied from 65° to 75° F.

It appears that 70° to 75° F. is a critical outside temperature range for this package, below which the cooling effects of the dry ice predominate over the heating effects of the environment. Above this critical range the temperature in the package farthest from the dry ice becomes too high after 48 hours, although a sufficient amount, 28 to 34 pounds, of dry ice was used. A greater quantity of dry ice did not reduce the temperature.

The gross weight of the package which held 24 pounds of dry ice and 40 pounds of fillets was 78 pounds. The outside dimensions were approximately 23 by 12 by 12½ inches.

It is important that the dimensions given for the various parts of the container assembly be closely followed. Any important changes in these measurements may cause variations in the thermal effects inside the container or may upset the insulation balance so that poor performance may result even under cool outside temperatures. Thorough sealing of the container is necessary so that a carbon dioxide envelope is maintained around the fillet boxes.

CONCLUSIONS

1. A method of packaging fresh cod and haddock fillets for shipment with dry ice is described, which gave a satisfactory performance under laboratory conditions.

2. Packages containing two 20-pound fibreboard boxes of fresh cod or haddock fillets were held satisfactorily for upwards of 48 hours with 28 to 34 pounds of dry ice, under outside temperatures of 75° to 90° F.

3. The temperature range of 70° to 75° F. outside the package is critical, below which cooling effects of the dry ice are predominant over the heating effects of the environment. When the package containing dry ice and fish fillets is exposed to the outside temperature range of 75° to 90° F. the period of satisfactory packaging is limited to 48 hours regardless of the amount of dry ice used.

The results of this investigation indicate that dry ice (solid carbon dioxide) can be used to refrigerate fresh fish fillets packed in corrugated paper containers for shipment. Under certain circumstances exposure of fish to carbon dioxide has been found to improve the keeping quality, and longer periods of packing may be possible with dry ice than with wet ice. A package containing dry ice and fresh fish fillets can be made compact, so that it can be easily shipped together with other materials in railway express cars. Packages containing dry ice are dry, and there is no danger of water damage to other goods, as would occur when water ice is the refrigerant.

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